IPPW-8 Abstract

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CO_2 Propulsion for a Mars Surface Hopper

Spirit and *Opportunity* (MER) rovers operating currently on the surface of Mars have returned valuable data about the liquid water history of the planet, but are very slow and cannot traverse difficult terrain. The lack of mobility over difficult terrain limits surface exploration to features that lie on relatively flat surfaces. By exploiting Mars' reduced gravity, a system that can fly over difficult terrain can provide the ability to achieve science objectives over a much wider range of potential targets. A hopper vehicle that can utilize ballistic flight trajectories over rugged terrain and reach otherwise inaccessible destinations can greatly expand mission capabilities. By heating frozen CO_2, condensed from the Martian atmosphere, a supercritical fluid can be created at modest temperatures within a pressure vessel and subsequently used as rocket propellant. A supersonic carbon dioxide rocket motor, operating in blow-down mode, has been designed, built, and tested for the purpose of evaluating this type of hopper propulsion system. The operation of the propulsion system on such a CO_2 hopper is as follows: Carbon dioxide is extracted from the atmosphere and stored under pressure in a tank; when enough CO_2 has been collected, the system is pressurized by heating the tank, and when a valve is opened the pressurized CO_2 rocket is activated. Such a system can augment the operation of a surface rover to allow access to areas that are currently inaccessible, and do so in a package that is small and simple in operation. The ability to refuel anywhere on the surface combined with the simple operation of the rocket will allow the system to operate for an indefinite time and investigate many interesting locations. Efforts at Old Dominion University are currently underway to characterize the performance of a small-scale rocket that utilizes supercritical CO_2 as a propellant for application on the surface of Mars. The apparatus used for testing consists of a pressure vessel to store the compressed CO_2, a valve to initiate the flow of CO_2, and a supersonic nozzle to accelerate the gas to Mach 2. The pressure vessel is filled with dry ice and sealed. The dry ice is then heated until the CO_2 reaches supercritical conditions. At which point the valve is opened, discharging the CO_2 to atmosphere, producing thrust. Stagnation pressure, temperature, thrust, and mass flow rate histories have been obtained so that specific impulse performance can be determined. Based on initial measurements it is possible to increase the time interval over which supersonic nozzle thrust levels can be sustained by heating the gas before it reaches the supersonic nozzle. Estimates of specific impulse are in the range of 100 to 130 seconds, while producing about 30 N of thrust through a nozzle with a 2 mm throat diameter. Since systems operating on Mars can take advantage of the low ambient pressure to produce supersonic flows with lower CO_2 pressures, enhanced performance for Mars surface probes can be anticipated.